DPF Meeting

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Top Quark Phenomenology at NLO QCD

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Top quark phenomenology is rich:

- large cross section
- top quark mass, spin, charge, branching fractions
- spin correlations, forward-backward asymmetry
- sensitive to new physics

This talk:

arXiv: **0907.3090** [hep-ph]

Predictions for hadronic production of
top quark pairs and their leptonic decays
at NLO QCD

flexible MC program:

- accounts for all spin correlations
- allows for arbitrary cuts

$t\bar{t}$ production beyond leading order QCD:

first analytic results: [Nason, Dawson, Ellis, 1990] total $t\bar{t}$ production cross section
[Bernreuther, Brandenburg, Si, Uwer, 2001] production+decay
+ various threshold corrections, electroweak corrections

programs: MCFM: NLO $t\bar{t}$ production, no top decay

PowHeg, MC@NLO: NLO $t\bar{t}$ production, LO top decay

our program: NLO $t\bar{t}$ production and NLO leptonic decay

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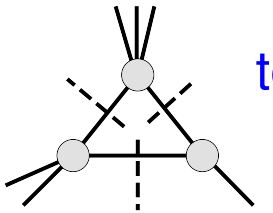
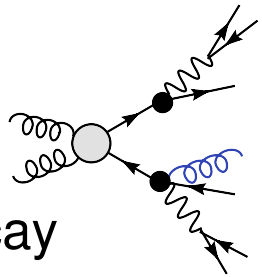


top production:
- virtual corrections using *D*-dimensional generalized unitarity
- real corrections using dipole subtraction method

top decay:
- on-shell approximation, error $\mathcal{O}\left(\frac{\Gamma_t}{m_t}\right)$
- retain all spin correlations
- include virtual and real corrections to decay



Results:

Predictions for:
- Tevatron
- LHC @ 10TeV

Realistic final states: di-lepton final state

require two b-jets (k_{T}-clustering with $R = 0.4$)

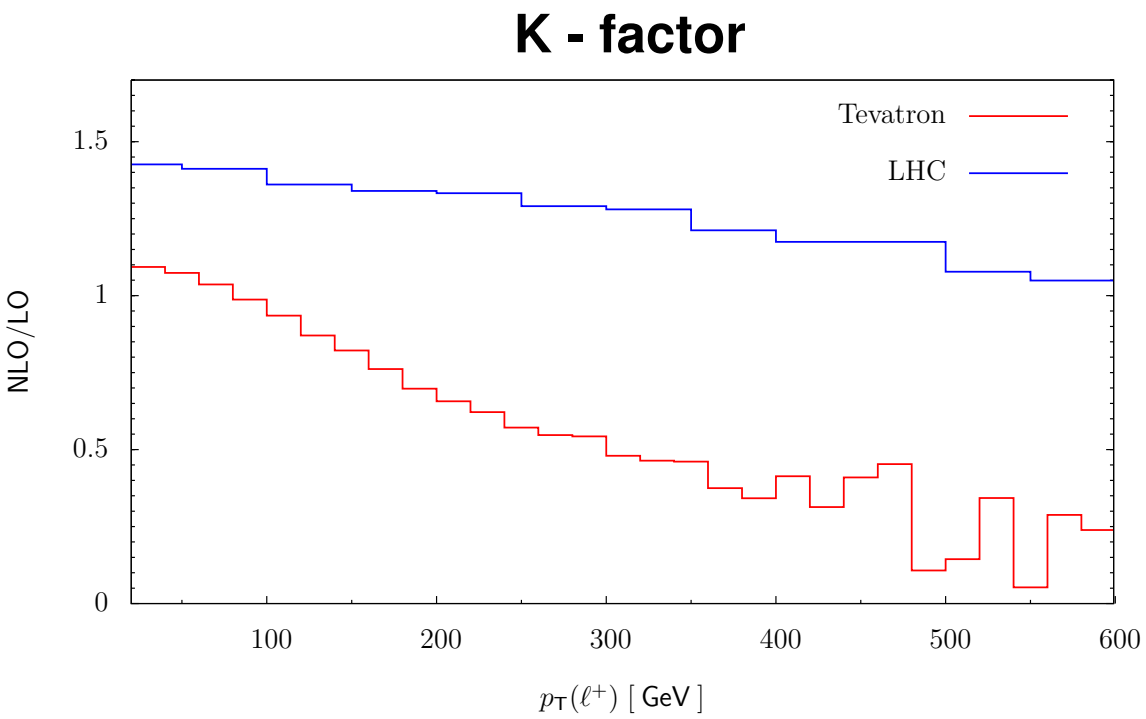
Cuts:

$$p_{\mathrm{T}}^{\mathrm{b-jet}} > 20 \text{ GeV}$$

$$p_{\mathrm{T}}^{\ell ep} > 20 \text{ GeV}$$

$$p_{\mathrm{T}}^{\mathrm{miss}} > 40 \text{ GeV}$$

Results:



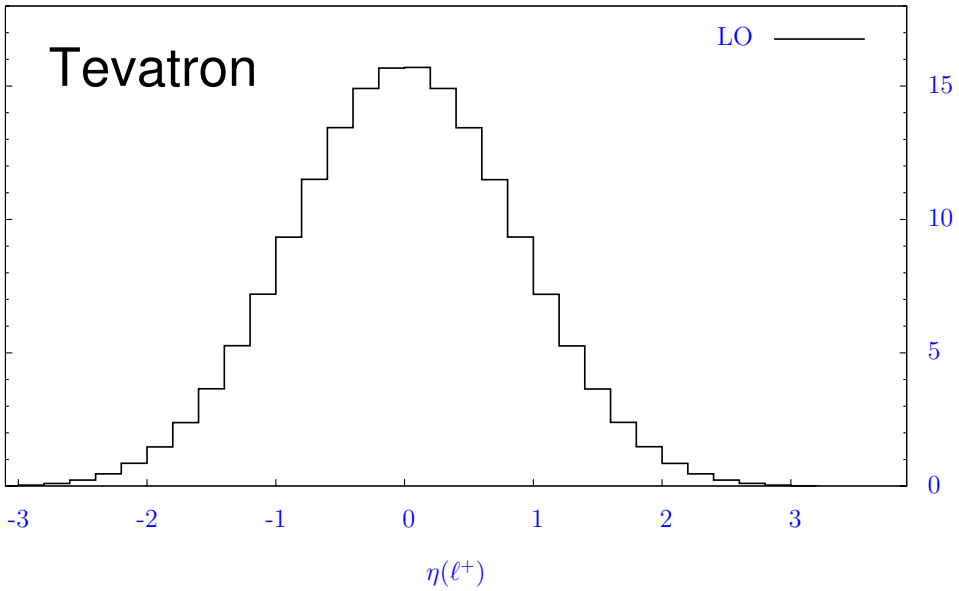
K-factors are not constant

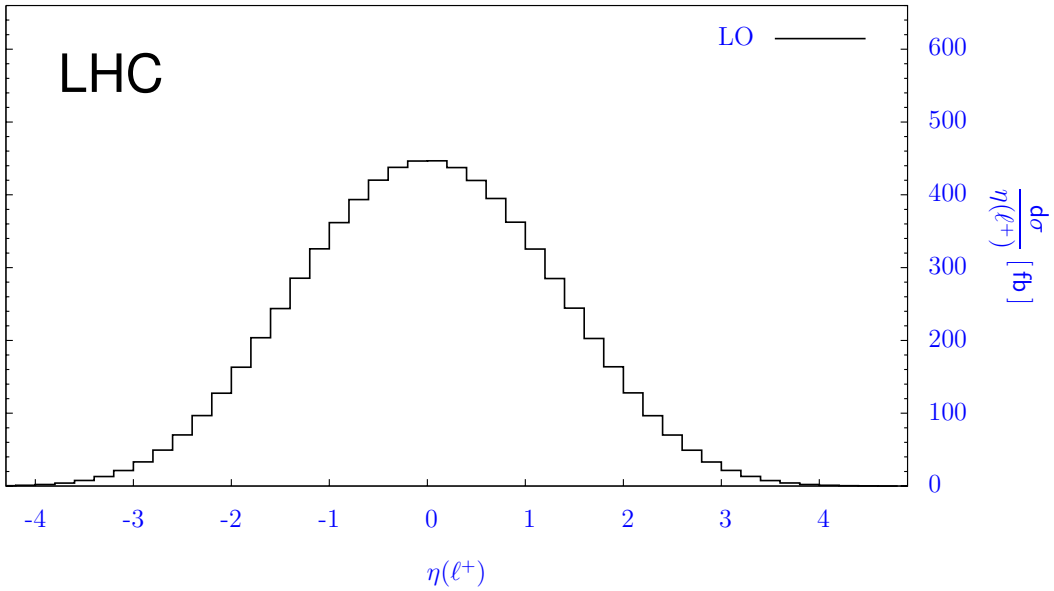
Tevatron: NLO change pT-distribution significantly

LHC: smaller change but non-negligible

Results:

lepton rapidity distribution

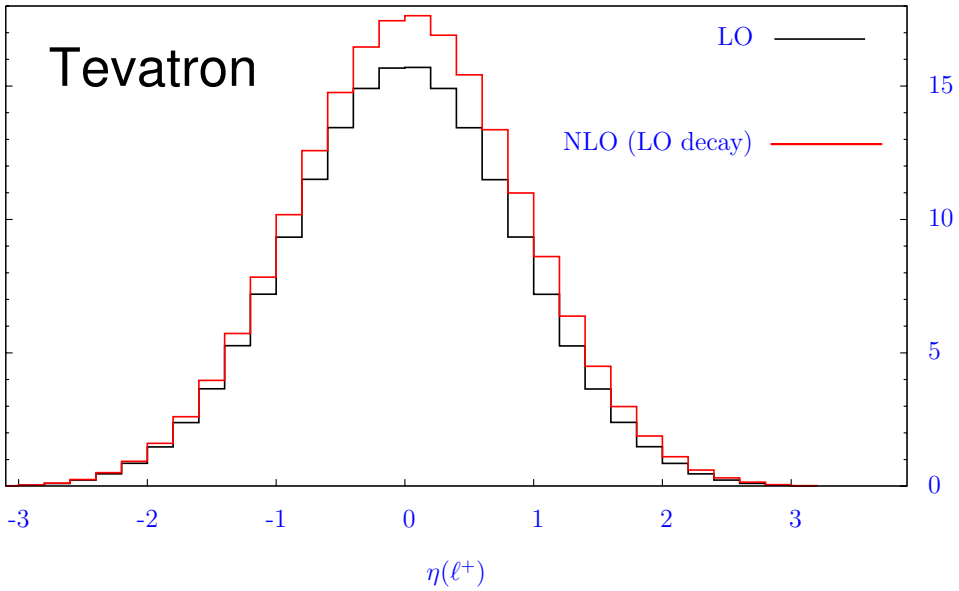


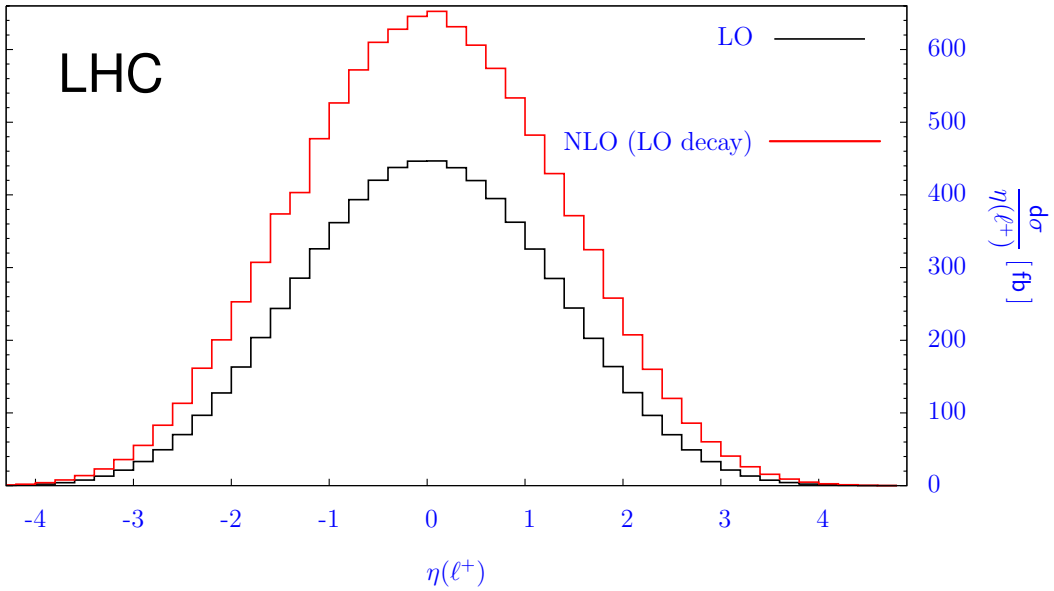


- NLO corrections to rapidity distribution are important
- NLO correction to decay shifts rapidity distributions significantly

Results:

lepton rapidity distribution





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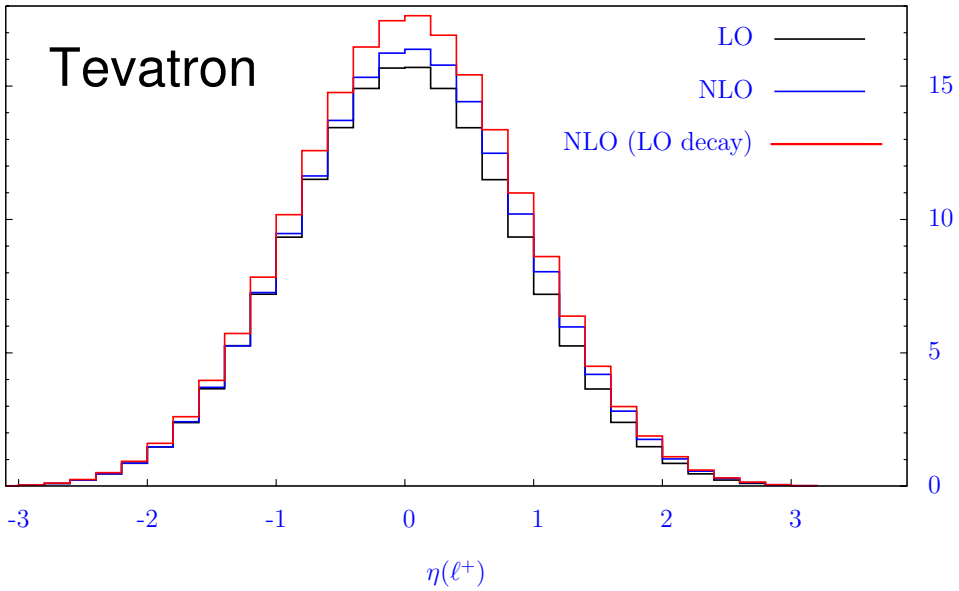

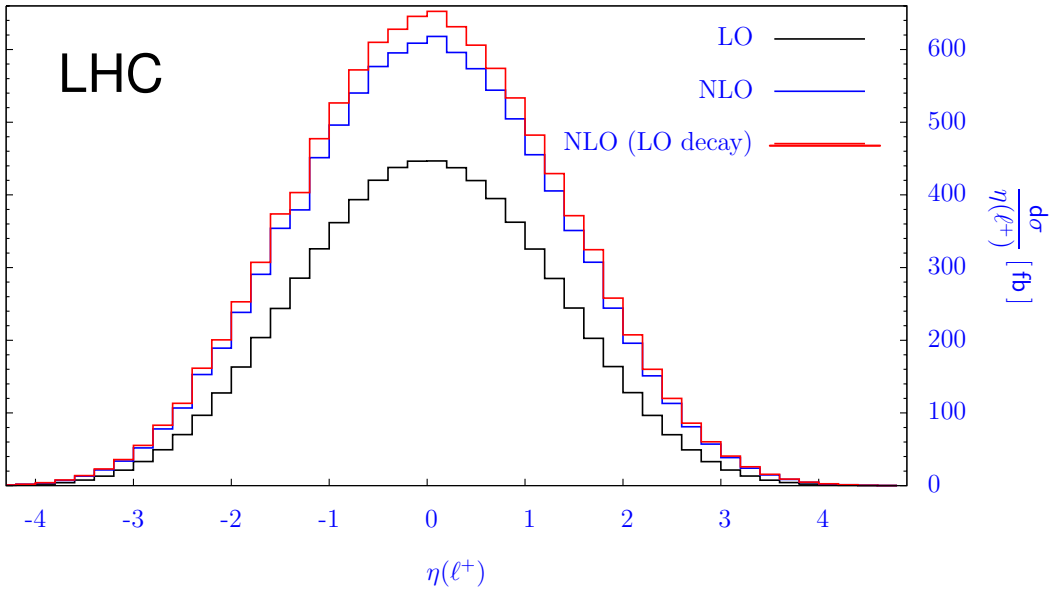

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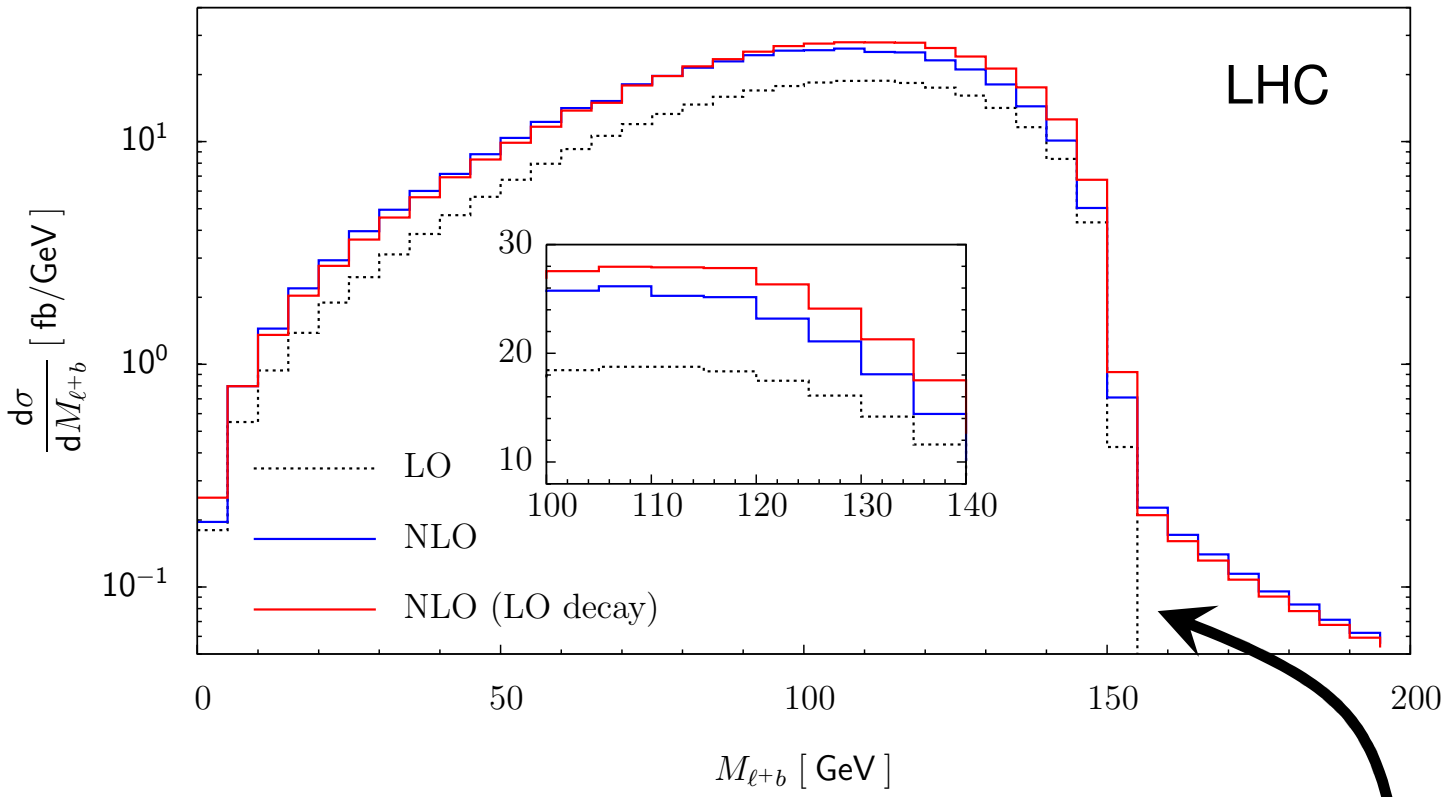
Results:

invariant mass of lepton and b-jet $M^2_{\ell^+ b} = \big(p(\ell^+) + p(\text{b-jet})\big)^2$

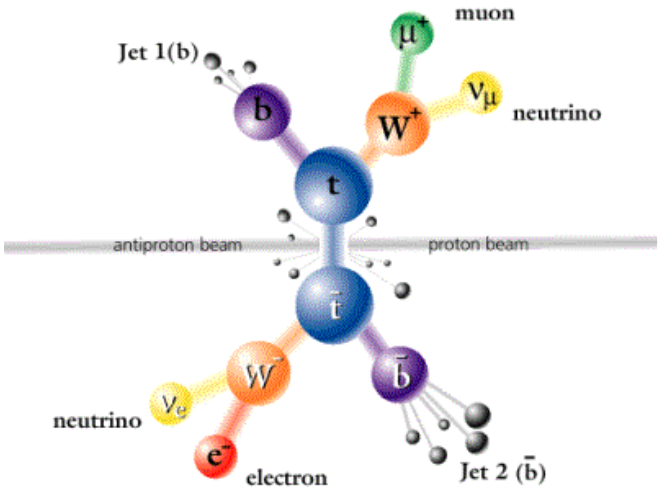


$$\max(M^2_{\ell^+ b}) = m^2_{\text{top}} - m^2_W$$

- boundary is top mass dependent
- spin studies for BSM particles
- NLO induces a tail

Results:

spin correlations



- large mass and short life time prevent hadronization effects to wash out spin information

  ⇨ top spin correlations induced by production process are conserved

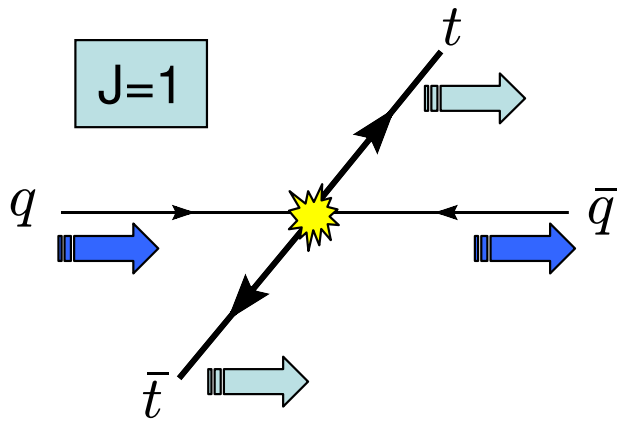
- spin correlations are strongest close to threshold

- spin correlations of top quarks are passed to decay products

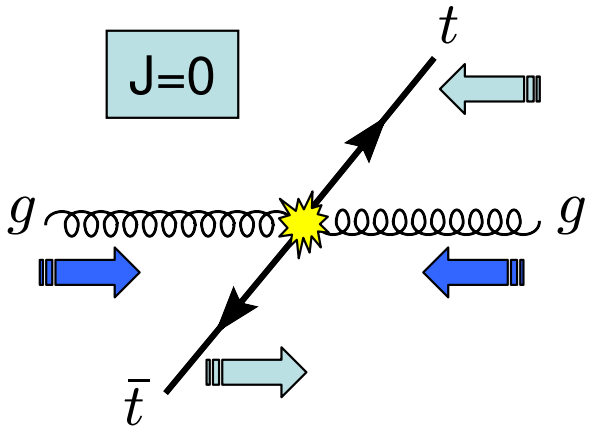
  ⇨ leptons prefer to fly parallel or anti-parallel wrt. each other

Results:

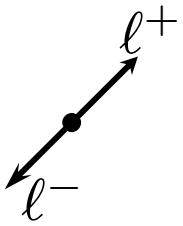
spin correlations



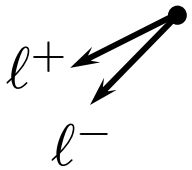
close to threshold:
S-wave production
(L=0)



⇨ leptons preferably anti-parallel



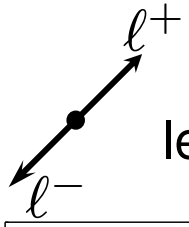
⇨ leptons preferably parallel



typical observable:

$$\frac{1}{\sigma}\frac{\mathrm{d}\sigma}{\mathrm{d}\cos(\varphi_{\ell^+\ell^-})}$$

$\varphi_{\ell^+\ell^-}$: angle between the directions of flight of leptons in the corresponding ***top rest frame***



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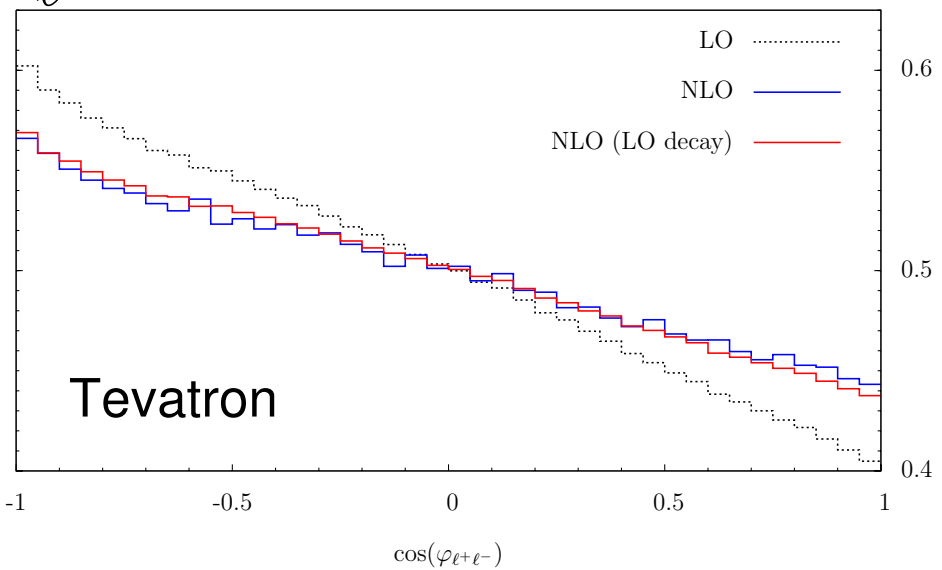

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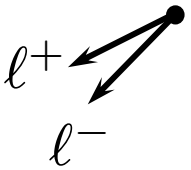
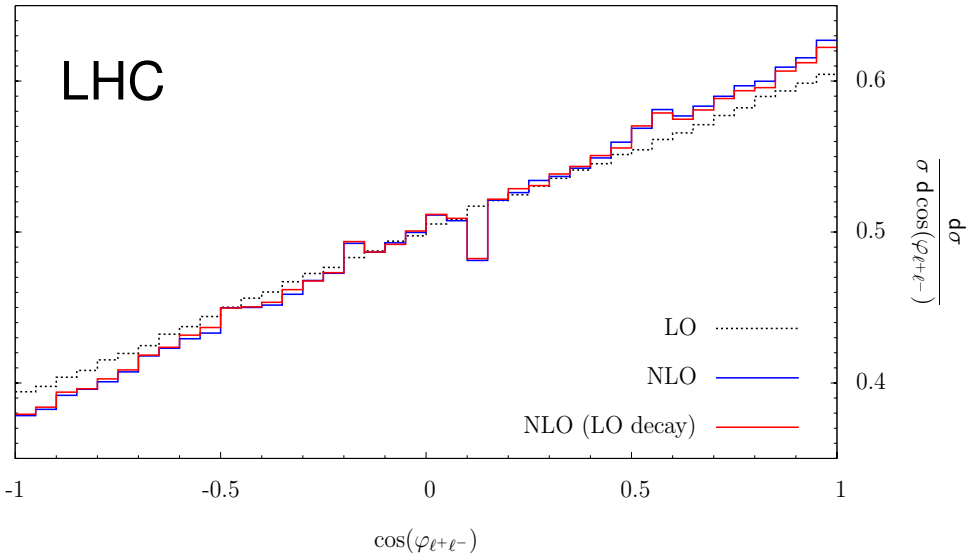


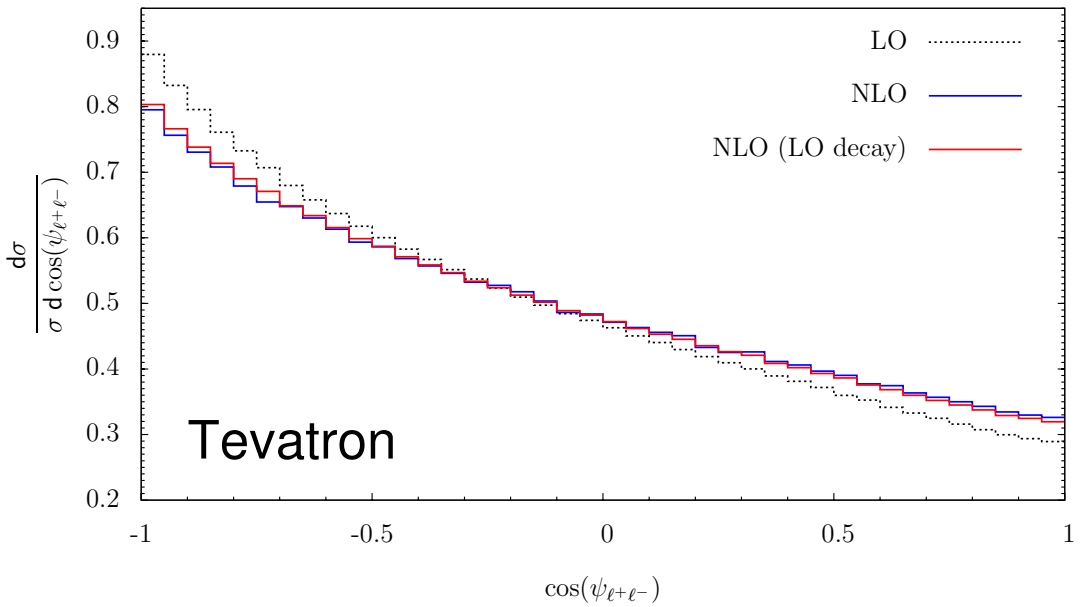


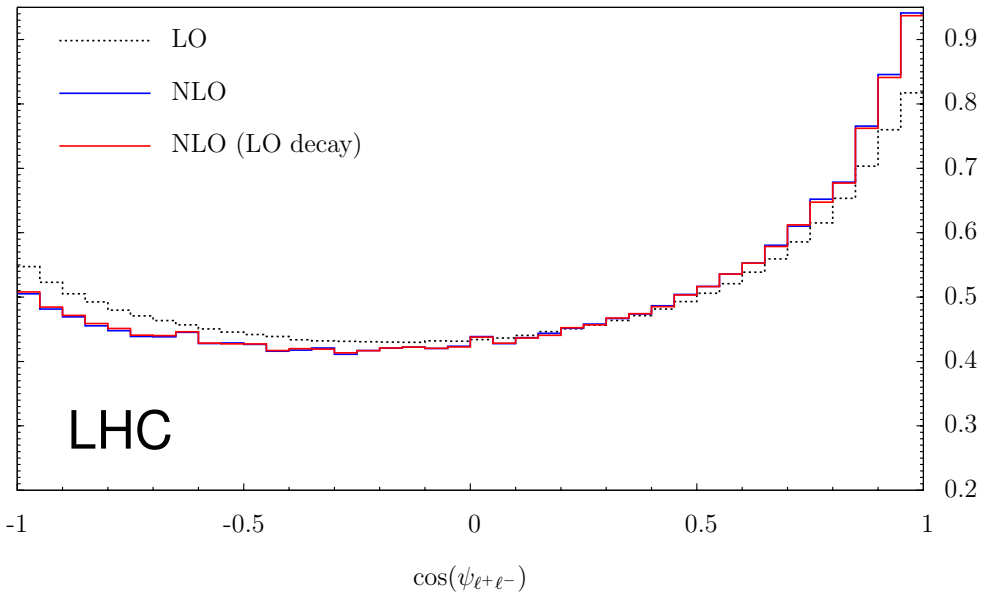
- substantial angular correlations, even at NLO
- NLO effects at Tevatron are significant

simpler observable:

$$\frac{1}{\sigma}\frac{\mathrm{d}\sigma}{\mathrm{d}\cos(\psi_{\ell^+\ell^-})}$$

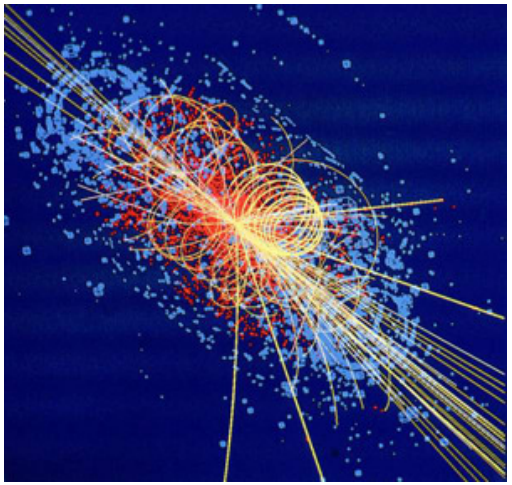
$\psi_{\ell^+\ell^-}$: opening angle of the leptons in the ***laboratory frame***





- top quark rest frames need not to be reconstructed
- angular correlations remain, stronger NLO effects at LHC

Summary



- top quark pair production and leptonic decay at NLO QCD
- flexible MC program based on *D*-dimensional generalized unitarity
- interesting distributions sensitive to spin correlations and NLO QCD corrections